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Chicago Transit Authority Turnstile Pass Reader System

Final Report
August 1987

cta

UMTA Technical Assistance Program

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16. Abstract

CTA augmented its successful "flash" pass program by incorporating current turnstile pass reading technology with its existing rapid transit station turnstile equipment. The CTA required that the turnstile pass reader be passive, i.e., the patron would slide a special magnetically encoded card through a slot on the turnstile which would open the gate if the pass was valid. Validity would be determined by a series of computerized checks to prevent fraudulent use of the fare card. The CTA concept was based on a system developed by the Massachusetts Bay Transportation Authority (MBTA), but incorporated a number of significant design and functional advances including a series of data capture requirements.

CTA successfully demonstrated its pass reader system at 2 turnstiles utilized by CTA employees between January 1982 and October 1984. This report documents the CTA Magnetic Card Slide Thru Reader System, including system reliability and employee reaction to the equipment.

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CHICAGO TRANSIT AUTHORITY

TURNSTILE PASS READER SYSTEM

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Chicago Transit Authority
Chicago, Illinois

FINAL REPORT
August 1987

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

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EXECUTIVE SUMMARY

In November 1978, the CTA implemented a monthly "flash" pass for rail and bus riders. The success of this program fostered a desire to examine methods of improving passenger flow of patrons using passes, and improve the security of passes. The ensuing study revealed that the use of a magnetically encoded pass access system would remove pass users from the ticket agent lanes, thus speeding passenger flow through the station. The security aspects of magnetic cards were also felt to be paramount to a monthly pass system.

After studying the CTA's needs, the benefits of a card access system and the success of the Massachusetts Bay Transportation Authority's (MBTA) system, CTA decided to proceed with a test of a magnetic pass on the rail system by interfacing card reader technology with existing turnstile equipment.

CTA's engineers, after analyzing the MBTA system, designed a system stressing card security, a secure "stand-alone" concept, and "off the shelf" components. To accomplish this the CTA decided that all software for the project would be written "in house" and all hardware would be off the shelf components available from a variety of suppliers. Thus, if required the CTA would be capable of modifying the system without the necessity of outside help, and would never be tied to one manufacturer for parts. In other words, the system would be designed to be as flexible as possible.

Utilizing these concepts as a foundation, the system design took shape. Under this grant the "stand-alone" turnstile and the station controller modes were designed and tested. In its final stage a magnetic pass equipped rail station would also include an agent's verifier and data capture. The future agent's verifier would allow a ticket agent to determine the reason, if a passenger was denied entry at a turnstile.

At the turnstile level, each present machine would be retrofitted with a card reader system consisting of a reader/signal amplification board, power supply, single board computer, and necessary interface cabling. At the turnstile the card would be read, checked for valid date and against the stack of previously used cards at that turnstile. The station controller would accept queries from the individual turnstiles as to the correct date and maintain a station wide stack against which each incoming card from all turnstiles would be checked. The turnstiles and the station controller interface to form a network in which if any part of the system fails, the entire system will not suffer loss of operation.

1.1 INTRODUCTION

In 1978, CTA inaugurated a monthly "flash" pass program. These passes were made available to companies in lots of ten or more. The success of the limited sale program and burgeoning public interest eventually led to the CTA offering a combination bus and rail monthly pass to the general public in November, 1979. The pass program has gradually increased and peaked at 130,000 monthly passes in April, 1981.

Prior to the pass program, 225 automatic coin operated turnstiles were purchased and installed around the CTA rapid transit system through the CTA Capital Improvement Program. These turnstiles were obtained in an effort to increase the efficiency of collecting fares during peak periods.

Though the monthly pass program and automatic coin operated turnstiles facilitated passenger flow through the turnstiles, these two means of fare collection were mutually exclusive. Pass holders were required to display their pass to an agent, and therefore could not use the automatic turnstiles. Thus, pass holders who had pre-paid their fare were inconvenienced by the added time required to use an agent controlled line.

At an UMTA - sponsored transit system workshop on fare collection held on March 11, 1980, there was consensus that development of a successful pass reader was of the highest priority to those involved in fare collection. The CTA proposed to incorporate current pass reading technology with its existing turnstile equipment. Pass readers had been developed by several companies, but little was done in the area of retrofitting existing turnstiles and reliability testing. Many new systems had transport type ticket reading equipment that occupied a much larger space than available in coin only turnstiles. For simplicity of operation and spatial considerations, a non-transport type of device was sought in which the pass owner would maintain possession of the pass when moving through the turnstile.

Incorporating pass reader equipment into CTA turnstiles presented several challenges. The pass needed to be redesigned to be machine readable, yet allow continued visual recognition necessary for use on buses. The turnstiles would also need to undergo significant redesign to allow for the addition of pass reader components.

The benefits of having reliable pass reading equipment appeared to be significant for CTA riders and for the CTA itself. For CTA riding pass holders, the availability of such equipment would allow a much faster means of passing through the fare collection area by avoiding the sometimes long agent controlled lines. For those riders in need of agent services, diversion of those with passes away from line would mean their line would become shorter.

FIGURE 1.1. CARD READER RETROFITTED TO CTA TURNSTILE

For CTA, a successful pass reader could eliminate the need for assigning extra agents at some locations during rush periods. This system would also help minimize pass forgery and "pass back" problems. "Pass back" is the situation in which a pass is used to gain access to the paid area and then passed back to others in the non-paid area. In the long term it was predicted that the decrease in the time spent by the pass user in going through the fare collection gate would stimulate monthly pass sales. Ultimately, the CTA foresees the pass reader as usable at agent windows, and on the surface lines (buses) when suitable equipment is developed.

Before beginning work on their card reader system the Chicago Transit Authority critiqued other magnetic card access systems being used. Since the Massachusetts Bay Transportation Authority (MBTA) had already tested a turnstile based pass reader system the CTA utilized several MBTA concepts which are integral to a reliable and secure system. These included certain aspects of system security and operation goals as discussed in the subsequent section.

1.2 SYSTEM DESCRIPTION

The Pass Reader system was developed as an integrated system operating within and through the hardware of a single board computer. The software is composed of four basic components: (1) the portion which programs the programmable support/peripheral hardware chips, (2) the segment which initializes system control variables stored in the SBC RAM, (3) the segment which deals with card transactions to produce either the continue locked turnstile or open turnstile situation, and (4) the segment for assuring that the system queues, pointers, stacks, and other variables have correct, updated values.

The hardware is centered around an Intel 80/24 single board computer. This printed circuit board is 5 by 11 inches in size. It carries an Intel 8085/A microprocessor as the MPU, two programmable parallel communications chips (8255 PPI), one programmable serial communications chip (8251 PSC), and one programmable interrupt controlling chip (8259/A PIC), and one programmable interval timing chip (PIT), 4 K bits of RAM, sockets for four EPROM chips of capacity up to 32 K, TTL logic to support and interface these chips among themselves and the outside world, ports by which the board may communicate with and be communicated to, from the outside world (edgewise connectors, other ports), and sockets for the connection of additional hardware boards (called SBX) to the main computer board system.

For system security the choice of using high energy magnetic media is paramount. The high energy magnetic media means that the magnetic message on the card is about 10 times stronger than that of standard magnetic media. The stronger media means that

if a valid message is copied to a card with standard magnetic media the duplicated card will not be accepted as valid when used for transit entry. This is due to the special equipment which is required to put the information on the stripe, or actually do the encoding. This equipment is much more expensive and not widely used as the low energy equipment associated with the banking industry. Thus, just to circumvent the first level of protection that is used, a potential counterfeiter would have to make a sizeable investment in equipment. Along with the equipment being somewhat difficult to obtain, the high coercivity magnetic media on which the information is encoded is not as common an item in the banking/magnetic card industry. By selecting high energy media and placing a magnet in the forward part of the readhousing; if the data is copied to a low energy stripe, the information will be erased before it is read. An additional major consideration for using high energy media is its reliability to keep the data intact on the stripe. It makes it virtually impossible for a passenger to have a card accidently erased. We are assured that the pass will work reliably every time.

The second level of counterfeit protection is the encryption of the data that is stored on the cards. This encryption algorithm was devised by the CTA. All data on each card is randomly scrambled making the system uncompromisable, even to the designers.

Another MBTA feature is the means of preventing PASS-BACK while using the card in the READ ONLY mode. The READ ONLY card is the most reliable method of utilizing a magnetic message since the message, using high energy, is never changed or distorted. However the READ ONLY method does not allow the versatility to recognize transactions being performed as in the READ/WRITE mode. MBTA devised this means to prevent passengers from using their card, and then handing it to another passenger to use again.

Another important MBTA concept involves the use of a hand motivated swipe reader. This reader is the least expensive method of reading magnetic cards, and requires very low maintenance. The patron's hand provides the transport mechanism thereby eliminating all moving mechanical parts from the reader assembly.

The concept of an agents' verifier is an MBTA concept required to resolve disputes with passengers. When a card is wiped through the reader the verifier displays a code to the agent, indicating the validity or reason for non-validity of the card. The major differences between the MBTA and CTA systems is the amount of intelligence incorporated into the turnstile's card reader as described in Table 1.

Table 1. COMPARISON OF MBTA AND CTA READER SYSTEMS

	MBTA		CTA	
	Turnstile	Controller	Turnstile	Controller
a) Station anti-passback* Controller time Normal Oper.	MBTA Format	MBTA format 100 types 10 values day/wk/mo/yr anti-passback	CTA format 100 types 10 values day/wk/mo/yr	download
b) Stand Alone Mode Controller out of service	MBTA format	-	CTA format 100 types 10 values limited anti-passback	-

* except for the future agent's verifier which will check all data.

Under a) NORMAL OPERATION, the MBTA controller must make 4 separate checks plus a check for anti-passback for each pass for each turnstile. This may overburden the controller and limit the versatility of the system. Each CTA turnstile performs numerous checks of passes, leaving the controller memory open to perform other functions.

Under b) CONTROLLER OUT OF SERVICE, the MBTA's turnstile checks the MBTA format only. This is a most definite weakness especially considering that the controller may be overburdened during given periods. Each CTA turnstile performs numerous checks to validate each pass.

The CTA system is designed to initially be implemented as a STAND ALONE only system. Under this system two turnstiles at each station would be interconnected allowing an anti-passback check between them to be performed. Each turnstile has the capacity to act as a controller if an adjacent turnstile is connected to it. The STAND ALONE system can be implemented much quicker and at a cost savings from the same system with the station controller. The turnstile hardware and software is compatible to operate with a station controller if it is added at a later date.

The data required to be captured by MBTA did not meet CTA's requirements. This is described in Table 2.

Table 2. Data Capture Requirements By CTA and MBTA

MBTA	CTA
-all pass entries by pass number -by 8 turnstile lanes -by one minute intervals	-all pass entries by pass number -all passenger entries at station for minimum of 25,000 passengers -by 16 turnstile and agent -by five minute intervals -minimum of 24 hour period

MBTA uses the data capture to trail pass entries by whom, when, and how often. The total passenger entries by station are not of enough importance for the MBTA to capture. The CTA however considers the total passenger entries by station of importance. The total station passenger entries are tabulated to indicate system traffic flows by time, entrances, and routes. This information can be used to plot future equipment and agent requirements by time, entrances, and routes.

The final consideration in examining the MBTA system was the versatility of the system to be designed. The CTA system was designed to interface with system components from different suppliers. The system was also designed with the capability of being programmed for unlimited transit system formats and requirements.

1.3 SUBSYSTEM DESCRIPTION

1.3.1 General Description of Components

<u>Turnstile components for STAND ALONE MODE</u>

Each turnstile has a slide-thru magnetic stripe (read only) card reader, a power supply, a board to interpret signals from the card reader, and a microcomputer.

<u>Station controller components for STATION CONTROLLER MODE</u>

The current station controller contains a battery backed-up timing control unit and a microcomputer.

<u>Agent verification components for STATION CONTROLLER MODE</u> (FUTURE)

Each Agent position will have a slide-thru magnetic stripe (read

only) card reader, a board to interpret signals from the card reader, and a display to indicate date, time and valid/invalid pass codes.

Additional requirements

The system requires high coercivity (4000 oersted) magnetic ink or tape. The cards are credit card sized, polyester and .010 inches +10% thick. A manner in which to void the use of low coercivity (300 oersted) magnetics in cards is provided.

1.3.2 FIELD EQUIPMENT

1.3.2.1 READHEAD AND HOUSING

The housing is constructed of stainless steel. The readhead is a high quality laminated readhead permanently adjusted to maintain the correct pressure to read any and all card thicknesses between .010 inches to .026 inches over the life of the readhead.

The readhead housing also houses the pre-amp board which conditions and amplifies the signal and sends the signal to the single board computer. Also contained within the housing is a magnet at the leading edge. This is the magnet used to erase any low energy passes which would be considered counterfeit.

1.3.2.2 CASES AND ENCLOSURES

Before describing the enclosures that house the various components of the system, the philosophy or intent of the enclosures relative to the proposed maintenance procedures should be discussed.

The approach taken to maintain the system is that whatever is needed to be done in the field, to correct a malfunction, should be done in a minimum of time by first determining the bad module or component, isolating and then replacing that module. The malfunctioning component would then be sent in to a shop for board level repair. Thus, the modules must be easy to remove and install and able to survive transportation from the rail station, where the turnstiles are located, to the shop and back to the rail station.

It is felt that if proper enclosures were designed, the "Black Box" theory could be employed. Past experience showed times when the printed circuit boards were repaired and tested in the shop and then sent back out to the field, various components were broken off and the boards arrived in bad-order.

The enclosures designed by CTA engineers were intended to properly protect the components both while they were in use and when transported. They also lent themselves to ease of removal and installation. All connectors being metal military screw type, and each being different, assures proper and easy connection under all conditions.

Also an integral part of the design of the enclosure was convection cooling. Proper ventilation was considered due to the fact the printed circuit boards were being totally enclosed. If found necessary, steps could be taken to warm the enclosures in the winter months, however, they would have to function properly in the warmer months without additional cooling.

1.3.2.3 POWER SUPPLY AND HOUSING

The power supply provides +5 volts, +12 volts, and -12 volts. The power supply is housed in a stainless steel cabinet. All connectors to other components are military type screw on.

1.3.2.4 SINGLE BOARD COMPUTER AND HOUSING

The single board computer utilizes an Intel 8085/A microprocessor chip, 4 K of RAM, up to 32 K in EPROMS, and RS 232 serial ports. The SBC has a minimum on-board CPU addressing capability of 64 K. The single board computer is housed in a stainless steel cabinet. All connectors to other components are military type screw on. Peripheral multimodule boards are required to expand the I/O capabilities and provide a timing mechanism.

1.3.3 STATION CONTROLLER EQUIPMENT

The equipment listed below describes the Station Controller in service from November 1983 until October 1984. The further development of the Station Controller has been halted due to lack of funding and due to the evaluation made by CTA that an IBM XT or comparable personal computer would better serve the purpose.

1.3.3.1 CONTROLLER CHASSIS

The chassis is an 8 slot, air cooled, Intel Multibus compatible cardcage. The chassis power supply provides +5 volts, -5 volts, +12 volts, and -12 volts. All connectors to other components are military type screw on.

1.3.3.2 SINGLE BOARD COMPUTER

The single board computer utilizes an Intel 8085 Microprocessor chip, 4 K of RAM, up to 32 K in EPROMS, and RS 232 serial ports. The SBC shall have a minimum on-board CPU addressing capability of 64 K. Peripheral multimodule boards are

required to expand the I/O capabilities and provide a timing mechanism.

1.3.3.3 PERIPHERAL BOARDS

Multibus compatible peripheral boards are required to provide additional channels for communications and provide a minimum expansion of 128 K of non-volatile memory.

1.3.4 SPECIAL SUPPORT EQUIPMENT

1.3.4.1 MAGNETICALLY ENCODED CARDS

The cards have a high coercivity magnetic stripe positioned to be read in an ANSI standard track 2 reader. The 4000 oersted, high coercivity magnetics, can be in the form of tape or ink. The cards are credit card sized. A minimum of 10 mil thick, polyester card is recommended.

1.3.4.2 MICRO-COMPUTER DEVELOPMENT SYSTEM

The micro-computer development system is a stationary computer used to reprogram the micro-processor controlled, single board computer in both the turnstile and station controller.

1.3.4.3 HIGH ENERGY CARD ENCODER

The card encoder is a stationary unit capable of encoding a high energy message on cards with high energy coercivity magnetics. The encoder can be used to program cards, individual passes, or to make program cards to reprogram turnstiles.

1.3.4.4 VIDEO DISPLAY TERMINAL

The video display terminal (VDT) is a diagnostic tool that when connected to either the turnstile's single board computer or station controller will display various diagnostic functions.

1.3.4.5 PRECISION DRIVE SYSTEM (FUTURE)

The precision drive system is a card transport system used in conjunction with recording devices to test performance characteristics of the magnetic material used on cards. Transport velocity is very critical since the readback signals vary with velocity.

1.3.5 DATA COLLECTION EQUIPMENT (FUTURE)

A portable <u>data collection unit</u> is used to recover the stored data. The recovered data is processed by the Micro-computer Development System (MDS) to extract pass usage and passenger information.

1.4 SYSTEM OPERATION

The system involves CTA passengers purchasing magnetically encoded passes that can be passed through a hand motivated slide-thru (read only) card reader located on the top of an existing coin operated turnstile. The system determines the validity of the pass, and within one half second either opens turnstile and allows entry or determines that the pass is not valid and prevents entry by not unlocking turnstile.

1.4.1 STAND ALONE MODE OPERATION

If the station controller is not functioning or has not yet been implemented, at the moment a pass is passed through the card reader the following will occur:

The electronic pulses that are read off the magnetic stripe by the readhead are transmitted to a pre-amp board that amplifies and digitalizes the signal, sending a TTL level signal to the turnstile's single board computer. The information transmitted includes the card data, the clock pulse, and card present signal.

The turnstile's single board computer analyzes the signal from the pre-amp board and:

- De-encrypts the data to determine that the pass is a CTA pass.
- Checks that the card is the proper type (1000 types possible).
- Checks to determine that the time/date is valid. The time/date is electronically set via a hand held computer. The time/date is then automatically maintained through the program in the single board computer.
- Checks the serial number of pass against an internal stack of up to 100 passes used at that turnstile within the last 20 minutes.

If the single board computer determines that the pass is invalid, then the turnstile remains locked and the turnstile is ready for another transaction.

If the single board computer determines that the pass is valid, then a signal is transmitted to the turnstile's logic board to unlock the turnstile. The turnstile's logic board then unlocks the turnstile, allowing the passenger to enter. Simultaneously, the serial number of the pass is added to the internal stack of passes used in the previous 20 minutes. If there are already 100 passes on the stack, the first card on the stack is automatically removed by the entry of the 101st card, even if less than 20 minutes has expired. The turnstile is now ready for the next transaction.

If the system is implemented without a controller, each single board computer is capable of operating as a controller for two turnstiles. In this phase every two turnstiles would be connected and an anti-pass back check between these two turnstiles would be performed.

1.4.2 STATION CONTROLLER OPERATION

The station controller performs two main functions, that of setting and maintaining the correct time and date in each turnstile and maintaining passback protection between all turnstiles. The station controller maintains the correct time and date in each turnstile by automatically downloading the current time and date to each turnstile card reader every 60 seconds.

If the station controller is functioning at the moment a pass is used the following will occur. The electronic pulses that are read off of the magnetic stripe by the readhead on the turnstile are transmitted to a pre-amp board within each turnstile that amplifies and digitalizes the signal, sending a TTL level signal to the turnstile's single board computer. The information transmitted includes card data, the clock pulse, and card present signal. The turnstile's single board computer analyzes the signal from the pre-amp board to determine the following:

- De-encrypts the data to determine that the pass is a CTA pass.
- Checks that the card is the proper type (1000 types possible).
- Checks to determine that the time/date is proper.
- Checks the serial number of pass against an internal stack of up to 100 passes used at that turnstile within the last 20 minutes.

If the turnstiles single board computer determines that the pass is invalid, then the turnstile remains locked and the turnstile is ready for another transaction.

If the single board computer determines that the pass is valid, the passes unique serial number is transmitted, via an RS 232 level signal, to the station controller. The station controller then checks its internal pass-back stack to determine if the unique serial number had been used at any of up to eight turnstile entrances. The turnstile and station pass-back stacks are currently set at 100 passes, each pass is held on the stack for 20 minutes.

If the station controller determines that the pass is valid, then a signal is transmitted back to the turnstile's single board computer to unlock the turnstile. The single board computer then transmits a signal to the turnstile logic board to unlock the

turnstile,allowing the passenger to enter. The station controller has one half second to respond or the turnstile's single board computer will automatically send an unlock signal to the turnstile's logic board. Simultaneously, the unlock signal signifies that the serial number of the pass is to be added to both the turnstile's and the station controllers stack of passes used in the previous 20 minutes. If there are already 100 passes on either stack, the first card on the stack is automatically removed by the entry of the 101st card, even if less than 20 minutes has expired. The turnstile is now ready for the next transaction. This process provides an effective means of stopping the pass-back of cards between passengers among the several turnstiles at a given location.

1.4.3 SPECIAL FEATURES

The system design is such that both software and hardware changes can be made without requiring the purchase of a new system.

1.4.3.1 SOFTWARE

The software includes a complex CTA developed encryption code. Each card is encrypted randomly. However, if the code is broken, new codes would be generated through a CTA developed program, and then changed in the field.

The software can recognize up to 1000 different combinations of pass types, passenger categories, and value of passes. Each pass type, passenger category, or pass value can be selectively locked out by station entrance. The flexibility includes restricting card use by day, week, month, and year. A provision can be made for a grace period during which time both the recently expired card and the newly valid card can both be accepted as valid. The current system does not require reprogramming to change the system to accept new day, week, month, or years codes.

1.4.3.2 HARDWARE

The hardware used in the system are quality proven components that can be readily modified to accommodate a variety of system control applications. The construction of the exposed hardware is designed to be resistant to vandalism and tampering by the public or unauthorized personnel.

The system hardware as designed is able to accommodate changes to a different type system, such as from the current read only system to a read/write system with the addition of a read/write head mechanism, upgraded cabling and a new software package. Even changes to accommodate new technology can be incorporated to define new functions and operations.

Another hardware feature of the system, copied from MBTA, is the incorporation of a permanent magnet in the card reader housing. The standard 1200 oersted permanent magnet will erase any magnetic message on a card that has been encoded with 300 oersted magnetics. The high energy magnetic media used on CTA's passes has a coercive force of 3600 oersteds, and therefore is not affected by the permanent magnet.

1.4.3.3 SYSTEM CONCEPTS

The hardware and software must be fully compatible with prior fare collection procedures and existing turnstile equipment.

For complete station control, an agent verification unit (FUTURE) is required to resolve card validity disputes with passengers. The unit would duplicate the turnstile operation except that the card reader would be located inside the agents booth. The agent verifier would display a code to indicate to the agent whether the card is valid or not, instead of unlocking a turnstile as in the turnstile operation. The display will have 4 digits minimum. The display located at the agent's position inside the agent's booth will also be used for reading out the time and date. The clock will have battery back up.

For complete system control, under the future station controller phase, an analysis of card usage is necessary to reveal potential fraudulent card use. This could be accomplished with one station controller being designated as a system controller and accumulating all stations totals to analyze cards used more than "X" times in a given day. To accomplish this task efficiently requires clean telephone lines to all station entrances, not presently functional in Chicago, but possible in other systems. The manual transfer of data via non-volatile memory from all stations is a Chicago alternative to accomplish data collection tasks in a less efficient manner.

The anti-passback feature to prohibit the re-use of a pass is controlled by two factors: (1) the number of passes retained on current stack, and (2) the amount of time each pass remains on stack. These two factors are adjustable. The CTA stack is currently set at 100 passes and each pass remains on stack for 20 minutes.

After the turnstile's single board computer determines that the pass is valid and not on the turnstile's current anti-passback stack, the card serial number is sent to the station controller. If a response is not returned from the station controller within 400 milliseconds, the turnstile automatically unlocks, allowing the passenger to enter.

The system is designed so that the Authority can control system changes. Changes can be accomplished under authority

control, not requiring the input of the equipment manufacturer. The system is capable of updating current time in both the controller and each turnstile (if the controller is not in service). The time can be automatically downloaded via an RS 232 interface to the single board computer from a portable hand held computer.

1.5 PERFORMANCE DATA

1.5.1 DEMONSTRATION

The initial demonstration began in January, 1982. The demonstration involved giving 450 CTA employees magnetically encoded demonstration passes to enter via two turnstiles equipped with magnetic card readers. On the average 225 magnetic cards were used daily to enter the system. The two turnstiles were both connected to one single board computer (SBC). The SBC made all the verifications for both turnstiles including passback checks between the two turnstiles.

In July, 1983, the turnstile program was rewritten and installed in the two test turnstiles. The new turnstile program was written to communicate with the CTA developed station controller. To complete the stand alone concept, the new program required that a SBC be installed in each turnstile. Each turnstile is capable of operating by itself with the new program if the station controller is disconnected or becomes inoperative. In September, 1983, two additional turnstiles were retrofitted with card readers and SBC's. The four units in service each had a different model readhead indicating the flexibility of using standard components (see figure 1.2).

In October, 1983, the station controller was put into service. As with the first turnstile SBC, no protective self recovery software was implemented in the station controller. The station controller worked for one year until taken out of service in October, 1984.

1.5.2 QUESTIONNAIRE

A questionnaire was issued regarding pass reader use by CTA employees during the first nine months of operation of the stand alone system. The purpose of the questionnaire was to determine from the users standpoint how reliable the system was, how easy it was to use, how the system affected the flow of passengers, and how the users rate the system. (The questionnaire is contained in Appendix C.)

The questionnaire was distributed to the 450 pass reader project participants in October 1982. The results of the survey express a very positive reaction.

Of the 450 participants, 320 responses were received. Over three fourths of the respondents used the pass reader lanes at least several times a week. Eighty seven percent of the respondents stated their card always worked, another 9 percent (96 percent overall) stated that there was only one time when they could not enter. These rates seemed very high, since on certain days, when testing was in progress, passengers could not enter. The remaining respondents stated that on two occasions they could not enter. Over 99 percent of the respondents stated that the pass reader lanes at least slightly increased the passenger flow at the Merchandise Mart station, while 93.5 percent of these passengers stated that the pass readers greatly increased the entering passenger flow. 89 percent of the respondents had no difficulty in using the system, other than the first few times. Of the respondents having slight difficulty, 99 percent stated that it was only a momentary delay with no inconvenience.

Many comments on the system were received with the great majority being positive, such as "Implement systemwide", "Excellent system", "Speeds passenger flow tremendously", and even "Thank you. Its been great". The remaining comments mainly reflected improvements needed, such as "Redesign slot in card reader for easier card entry", "Use a different material for cards", "The current cards don't hold up", and "Please provide better instructions as to how to insert cards".

The participants were asked to rate the system on a zero to 100 point basis, where:

90 to 100 points = Excellent and simple to use

75 to 89 points = Very good system, slightly difficult to use

50 to 74 points = Satisfactory, but somewhat awkward to use

0 to 49 points = Difficult to use, very awkward

The average system rating from the respondents was <u>96.5</u>

1.5.3 RELIABILITY

During the first month of operation, in February, 1982, the turnstile program was modified to fine tune the actual in service operation of the system. For the next eleven months the system operated flawlessly.

The initial single board computer (SBC) program did not include any protective self recovery software. The reason for this is that CTA would not have known if there was an electrical interference problem or how severe a problem existed, if self

recovery software was implemented from day one. The program worked without a problem for over one year. In February, 1983, the program began locking up on a regular basis. A power line monitor was connected to the 120 volt A.C. line feeding the card reader system. The line monitor showed that the card reader lock-up coincided with a dip in the A.C. line voltage that occurred at 5:00 pm. each day. Further investigation found that a fire at the Merchandise Mart resulted in wiring changes made to the building. These wiring changes resulted in the Merchandise Mart station being connected to the same lighting distribution panel as several large new show rooms. When the show rooms would turn off their lights for the evening, the effects were causing the cardreader microprocessor to lock-up. CTA engineers then researched various types of lock-up, and subsequently implemented protective, self-recovery software into the program. The program monitors itself, and when necessary, resets itself. The SBC has not locked up since then, and CTA has determined that the protective software is a necessity.

During the first year of operation the CTA tested various card readers from different manufacturers. From the actual in field operation, CTA determined that a high quality read head and strong construction of its housing was required. Readers from two manufacturers operated intermittently due to a combination of low quality read heads and weak construction of the housing. Even in these cases the patron only experienced minor inconvenience since they could run their card through the reader again, or use another lane.

Occasionally during the four year demonstration, a foreign object would be wedged into a reader. The effect on the passenger usually amounted to minor inconvenience since their card was not lost and they could enter via another lane.

Three types of cards were distributed during this demonstration period.

TYPE OF CARDS TESTED

THICKNESS	CARD MATERIAL	MAGNETIC MEDIA
.022"	PVC	High coercivity tape
.022"	Polyester	High coercivity ink
.010"	Polyester	High coercivity tape

DURABILITY OF MATERIAL

.022" PVC	- Cards started cracking at about 3-6 months Some cards OK at 4 years.
.022" Polyester	- No card material failures

.010" Polyester - No card material failures, however if the card hits a foreign object in the reader, some cards became slightly damaged.

The .010" thick polyester card is recommended because the durability is sufficient for a monthly pass and the cost is 30% to 40% less per card than a .022" thick card. A paper card is not recommended due to being easily torn if a foreign object were stuck in the readhead throat.

The high coercivity tape is recommended over the high coercivity ink as tested. While the tape held up for four years unless purposely scratched with a sharp object, the ink flaked off of about 10% of the cards in the first few months, rendering them invalid for usage.

The only real turnstile card reader attributed failure in over four years of operation took place in February, 1984. One card reader went down and it was found that a capacitor on the pre-amp board failed and required replacement.

During the time the controller was in operation only one hardware problem occurred. CTA created the problem by purposely turning off the station controller's internal fans. This caused the printed circuit boards to overheat and the back up batteries on clock board to fail. After less than one year of operation the inside of the controller was quite dirty. CTA engineers determined the station controller would require cleaning a minimum of twice a year.

During the year in service the controller locked up a number of times. However, due to the design of the system, the station operation was not affected when the controller locked up. When the controller was removed from service in October, 1984, it was further tested under controlled conditions. The controller failed again and lockup was diagnosed. These software lockup problems were due to the fact that no protective self-recovery software was incorporated into the station controller at this design stage.

1.6 DESIGN ENHANCEMENTS

1.6.1 STATION CONTROLLER OPERATION AND AGENT VERIFICATION

A future enhancement to the station controller involves equipping each agent lane with a hand motivated slide-thru (read only) card reader. The operation is identical to the turnstile operation except that the card reader is located inside the agent's booth. The agent card reader would also be connected to a display instead of a turnstile. Upon passing the card through the reader, a message would be displayed indicating a valid or invalid card instead of unlocking a turnstile.

The station controller should be installed in a secure location remote from the agent's verifier. The purpose is to be able to secure the station controller in a location where it will not be tampered with, and a location where maintenance can be performed without interfering with the agent activities.

1.6.2 STATION CONTROLLER OPERATION DATA CAPTURE

Another future enhancement to the station controller would be to add the capability of retaining all station entry data by up to sixteen entrance lanes by five minute intervals. The memory would also retain the serial numbers of all pass entries by five minute intervals. The storage memory should be sufficient to store data for a minimum of 25,000 passengers in a 24 hour period. The capability of both removing the memory unit from the controller and transferring it to another location for data removal; and electronically removing the data automatically would also be enhancements.

1.6.3 STATION CONTROLLER

Initial development indicates that an industrial grade personal computer would best serve the purpose of a station controller, and would be far more cost effective. Although a single board computer was used in the initial CTA design and served its purpose, using high level languages such as "C" as opposed to machine language code is more practical. Due to the amounts of raw data that will be stored, a minimum 10 megabyte hard disk is recommended, such as the IBM XT. The high quality peripheral components required to develop a station controller, using an IBM XT, are available.

1.6.4 FIBRE OPTICS

The utilization of fibre optics would enhance the reliability of the data transmission in the harsh station environment. Due to the distances between communications, up to two hundred feet in certain applications, and considering the EMI and RF interferences anticipated, a more reliable means of data transmission, such as fibre optics should be considered.

FIGURE 1.2. FOUR MODEL READHEADS IN SERVICE

APPENDIX A

TECHNICAL CONTACTS

<u>Chicago Transit Authority</u>

J. C. Simonetti
Supervisor
1200 West Washington Blvd.
Chicago, IL. 60607
(312)243-2022 or 222-0200 Ext. 4161

*Dale Mangelsdorff
Project Manager

*C. M. Gaca
Unit Supervisor

*T. Canning
Project Engineer

*T. Kohler
Project Engineer

*S. Tucci
Project Engineer

* 321 S. Franklin
Chicago, IL. 60606
(312)922-0508

<u>Project Related Contacts</u>

Thomas Rowe
Just-Us Software
105 West 61st Street
Westmont, Il 60559
(312) 971-6247
Reference: Card Reader, Encoder and Controller Software
System Development Consultant
Data Security Consultant

Thomas McGreay
Mag-Tek
20725 S. Annalee Ave.
Carson, CA. 90746
(213)631-8602
Reference: Card Reader Hardware
Encoding Equipment

Dennis C. Jeffreys
Arthur D. Little, Inc.
Acorn Park
Cambridge, MA. 02140
(617)864-5770
Reference: System Evaluation Consultant

Bastion Knoppers
Cardpro
105 West 61st Street
Westmont, IL. 60559
(312)960-5640
Reference: Magnetically Encoded Cards
Encoding Equipment

Milton Taft
Magna-Graphics
12110 Clark Street
Santa Fe, CA. 90670
(213)946-3407
Reference: Card Manufacturing
Card Graphics

Joseph J. Sheppard
XICO, Inc.
120 Ocean Way
Santa Monica, CA. 90402
(213)459-1044
Reference: Card Reader Hardware

Gene Grosberg
Interface Control Systemics, Inc.
10231 Bach Boulevard
St. Louis, Missouri 63132
(134)423-0777
Reference: Card Reader Hardware

Keith E. Greenlaw
Massachusetts Bay Transportation Authority
South Station
650 Atlantic Avenue, Room 02210 Boston, MA.
(617)722-5667
Reference: MBTA System in Operation

Walter G. Armstrong
Metropolitan Transportation Authority
347 Madison Avenue
New York, NY. 10017
(212)878-7248
Reference: System Design for NYMTA

APPENDIX B

Chicago Transit Authority

October 15, 1982

To: All Pass Reader Project Participants

From: Director, Passenger Controls/Graphics

Re: Questionnaire on Pass Reader Use

At this point in the development of the CTA magnetic card system, we would like to find out about your experiences with the system. Please take a few minutes to answer the questions below. Your frankness and honesty in responding is important and will be kept confidential.

1. Male [ ] Female [ ]
2. Magnetic Card Number: 0 0 0 0 _ _ _
3. Age Group:
   - [ ] Under 26
   - [ ] 26 to 35
   - [ ] 36 to 45
   - [ ] 46 to 55
   - [ ] 55 Plus
4. How often do you use the pass reader turnstile lanes?
   - [ ] At least once a day
   - [ ] Several times each week
   - [ ] Whenever more convenient than agent
   - [ ] Infrequently
   - [ ] Not at all

8422 (rev. 04/76)

5. Other than the first few weeks, have you ever had to go through the agent lane because your magnetic card wouldn't work?

- /___/ My card always works
- /___/ Once, I couldn't enter with my card and had to enter through the agent lane.
- /___/ Twice, I couldn't enter with my card and had to enter through the agent lane.
- /___/ At least three times I couldn't enter with my card and had to enter through the agent lane.

Please explain? ____

____

6. How do you feel the pass reader affects the flow of passengers entering the station?

- /___/ Speeds entering flow greatly
- /___/ Speeds operation slightly
- /___/ Flow same as without pass readers
- /___/ Flow slower with pass readers

7. Have you experienced any difficulty in using the magnetic card?

A) <u>How often do you have difficulty</u>

- /___/ Not at all
- /___/ Only during first few weeks
- /___/ Seldom
- /___/ Once every two weeks
- /___/ often, at least once a week
- /___/ other, please explain? ______________________________

____

B) <u>Extent of difficulty</u>

- /___/ Only momentary delay, no inconvenience
- /___/ More inconvenient then I believe it should be
- /___/ Frustrating and/or embarrassing
- /___/ other, please explain? ______________________________

____

8. Please rate the pass reader, magnetic card system being tested. On the basis of zero to 100 points, where:

[ ] points system rating	90 to 100 points - Excellent and simple to use
	75 to 89 points - Very good system, slightly difficult to use
	50 to 74 points - Satisfactory, but somewhat awkward to use
	0 to 49 points - Difficult to use, very awkward

9. Do you have a preference for either of the two pass readers?

[ ] No

[ ] prefer shorter reader (right turnstile as you enter)

[ ] prefer longer reader (left turnstile as you enter)

Please explain? ______________________________

____

10. Additional comments. In the space below, please describe any unusual experiences, particular difficulties, suggestions for improvements, or questions about the system.

____

____

____

____

____

____

Your help is appreciated. Thanks for your assistance and cooperation in the development of a fast, efficient pass reading system for CTA. If you have additional problems or questions, please call Dale Mangelsdorff, EXT.4016.

Your continued, consistent use of the pass reader lanes in the Merchandise Mart is needed to test the reliability and life of various components. This experience, coupled with your comments and with observations of passenger flow, will be used in additional design modifications.

Later this year, the existing magnetic passes being tested will be exchanged for new passes. These new passes will be reissued to test participants found to have the greatest use for them.

PLEASE RETURN COMPLETED QUESTIONNAIRE TO:

Director, Passenger Controls/Graphics
Room 700
Merchandise Mart

RETURN NO LATER THAN NOVEMBER 15, 1982

J. P. O'Connor
Project Manager

Chicago Transit Authority

October 15, 1982

To: All Pass Reader Project Participants

From: Director, Passenger Controls/Graphics

Re: Questionnaire on Pass Reader Use

At this point in the development of the CTA magnetic card system, we would like to find out about your experiences with the system. Please take a few minutes to answer the questions below. Your frankness and honesty in responding is important and will be kept confidential.

1. Male [67]% Female [33]%
2. Magnetic Card Number: 0 0 0 0 _ _ _
3. Age Group:
   - [ ] Under 26
   - [30]% 26 to 35
   - [34] 36 to 45
   - [19] 46 to 55
   - [15] 55 Plus
4. How often do you use the pass reader turnstile lanes?
   - [58] At least once a day
   - [20] Several times each week
   - [10] Whenever more convenient than agent
   - [10] Infrequently
   - [ ] Not at all

8422 (rev. 04/76)

5. Other than the first few weeks, have you ever had to go through the agent lane because your magnetic card wouldn't work?

- [87]% My card always works
- [9] Once, I couldn't enter with my card and had to enter through the agent lane.
- [3] Twice, I couldn't enter with my card and had to enter through the agent lane.
- [ ] At least three times I couldn't enter with my card and had to enter through the agent lane.

Please explain? ______________________________

____

6. How do you feel the pass reader affects the flow of passengers entering the station?

- [93.5]% Speeds entering flow greatly
- [6.0] Speeds operation slightly
- [ ] Flow same as without pass readers
- [ ] Flow slower with pass readers

7. Have you experienced any difficulty in using the magnetic card?

A) <u>How often do you have difficulty</u>

- [71] Not at all
- [18] Only during first few weeks
- [ ] Seldom
- [ ] Once every two weeks
- [ ] often, at least once a week
- [ ] other, please explain? ______________________________

____

B) <u>Extent of difficulty</u>

- [50] Only momentary delay, no inconvenience
- [ ] More inconvenient then I believe it should be
- [ ] Frustrating and/or embarrassing
- [49.5] other, please explain? No comment

____

8. Please rate the pass reader, magnetic card system being tested. On the basis of zero to 100 points, where:

Avg. [96.5] points system rating

90 to 100 points - Excellent and simple to use
75 to 89 points - Very good system, slightly difficult to use
50 to 74 points - Satisfactory, but somewhat awkward to use
0 to 49 points - Difficult to use, very awkward

9. Do you have a preference for either of the two pass readers?

[89] No

[8] prefer shorter reader (right turnstile as you enter)

[3] prefer longer reader (left turnstile as you enter)

Please explain? ______________________________

10. Additional comments. In the space below, please describe any unusual experiences, particular difficulties, suggestions for improvements, or questions about the system.

See attached

Your help is appreciated. Thanks for your assistance and cooperation in the development of a fast, efficient pass reading system for CTA. If you have additional problems or questions, please call Dale Mangelsdorff, EXT.4016.

Your continued, consistent use of the pass reader lanes in the Merchandise Mart is needed to test the reliability and life of various components. This experience, coupled with your comments and with observations of passenger flow, will be used in additional design modifications.

Later this year, the existing magnetic passes being tested will be exchanged for new passes. These new passes will be reissued to test participants found to have the greatest use for them.

PLEASE RETURN COMPLETED QUESTIONNAIRE TO:

Director, Passenger Controls/Graphics
Room 700
Merchandise Mart

RETURN NO LATER THAN NOVEMBER 15, 1982

J. P. O'Connor
Project Manager

APPENDIX C

QUESTIONNAIRE COMMENTS

NEGATIVE COMMENTS

NUMBER OF OCCURRENCES	COMMENT
1	Bent card, had difficulty one time.
1	Card would not open gate twice.
1	Card was erased, didn't work in short reader, card was replaced.
4	Sometimes needs more than one pass through reader, but always works.
1	Some difficulty in getting the black stripe in proper place to allow entry.
1	Didn't work once when I went swimming.
2	The gate release could be a bit faster, upon rare occasion will hit bar.
1	I have to concentrate on getting it into slot, my eyes are not the best, maybe redesign the slot.
1	Had trouble when I quickly inserted the card in an arc. Is there a way to force me to insert card correctly?
1	Concerned about possible duplication.

POSITIVE RESPONSES

NUMBER OF OCCURRENCES	COMMENTS
1	I'm for automation, serving the public better.
1	A very good system, should have been available a long time ago.
10	Implement system wide!
3	Simple to use, I like using the pass reader.
7	Speeds passenger flow tremendously.
2	Excellent system
1	Works every time
1	Used with 100% success
1	Tremendous potential, it greatly facilitates entering traffic flow.
7	System works fine, it greatly facilitates entering traffic flow.
1	I think it is a wonderful system, beats standing in long lines.
2	The pass reader is a great time saver, it insures making on time connections.
1	The system has practically eliminated the lines that used to wind through the halls at 4:30. It's great! It seems to attract a lot of public interest (support as well).
4	It has worked perfectly. Feel sorry for passengers lined up at Agents booth. The card readers are very convenient, and greatly enhance the flow of traffic. I like the pass very much, glad I can continue using it.
1	Prefer readers over agent because you eliminate any problems of passengers asking questions, not having change, etc.

1	No difficulties whatsoever, keep up the good work.
1	So many people in the Merchandise Mart ask when they will be able to buy the pass.
1	I hope that it will be installed at all stations, I hope that we can develop it for our paying customers as they are impressed.
1	I'm impressed by how fast it reads the pass. I zip the pass thru the reader very quickly and don't wait to see the light. I have never "beaten" it ----- the turnstile always releases before I push it.
1	The system is great and should continue.
1	I have found the use of the magnetic pass a most efficient way of moving through the station.
1	Great job by CTA.
1	Great idea.
1	This is the greatest idea that CTA has come up with - its so fast and easy to use.
1	Implement as is.
2	Thank you, its been great.

MISC. COMMENTS ON INDIVIDUAL READERS

- Longer slot makes it easier to align card when entering.
- Widen opening for card.
- Suggest a photo diagram be placed at reader so people orientate card properly.
- Could be improved if card would feed through automatically at a constant rate since presently if pushed too fast it sometimes fails to work.

MISC. COMMENTS ON THE CARDS

- Clip corner to make card easier to align.
- Use four magnetic stripes for absolute orientation.
- Card cracks, need new material.
- You should test paper passes.

APPENDIX D

Drawings and Specifications

Power Supply: Dimensions, Description and Notes	DWG T-8401
Power Supply Chassis	DWG T-8402
Power Supply Adaptor Plate	DWG T-8403
Power Supply Cover	DWG T-8404
Power Supply Assembly	DWG T-8405
Single Board Computer Chassis	DWG T-8407
Single Board Computer Adaptor Plate	DWG T-8408
Single Board Computer Card Retainer	DWG T-8409
Single Board Computer Cover	DWG T-8410
Single Board Computer Assembly	DWG T-8411
Single Board Computercard Retainer Assembly	DWG T-8412
Card Reader Interconnection Cable Assemblies	DWG T-8413
Card Reader: Readhead Assembly	DWG T-8414
Magnetic Card Specification	CTA 5527-86
Single Board Computer	Intel 80/24 or Equivalent
I/O Expansion Multimodule Board	Intel ISBX-351 or Equivalent
Four Channel Communications Board	Intel ISBC-534 or Equivalent
Clock Board	Intel Multimodule Compatible

CHICAGO TRANSIT AUTHORITY

DETAIL SPECIFICATIONS
FOR
CARD: MAGNETIC CODED PASS, FOR CARD READER PROJECT

SPECIFICATION NO. CTA 5527-86

1. SCOPE

This specification covers the requirements for a magnetic coded pass card which includes the magnetic stripe, graphic printing, printed pass number and necessary coatings but does not include the encoding of the magnetic stripe. The magnetic coded pass card is part of the Card Reader Development Project.

2. PHYSICAL CHARACTERISTICS

The magnetic coded pass card shall meet the following requirements:

1. Material: The card exclusive of the magnetic stripe and finishes shall be polyester.
2. Thickness: The thickness of the polyester shall be 0.010" plus 0.002 minus 0.000 inch.
3. Overall Dimensions: See Figure A.
4. Position of Magnetic Stripe: See Figure A.
5. Location of Graphics: See Figure A.
6. Burrs: Edge burrs normal to the card face shall not exceed 0.003 inches above the card surface.
7. Straightness: No point on any edge of the card shall lie more than 0.004 inches from the straight edge against which that edge is registered.
8. Surface Finish: The average surface irregularity of the reading surface shall not exceed 16 microinches centerline average in either the longitudinal or the transverse direction using a cutoff wave length of 0.01 inch or 0.03 inches when using a probe having a minimum radius of 100 microinches.
9. Surface Profile: The average profile of the reading surface of the magnetic stripe, as measured parallel to the height of the card with a probe having a radius of 0.015 inch to 0.100 inch, shall show a deviation from high point to low point of not more than 0.00015 inch for each 0.100 of stripe width.
10. Integrity: The stripe shall not separate from the card or crack or flake during usage which includes 1,000 card swipes in the CTA card reader and which includes pocket and/or wallet storage deemed typical by the CTA.

3. PRINTING

3.1 Printing Schedule

The vendor and the responsible CTA department must keep the following procurement schedule in order that the monthly cards are available to the public at the proper time:

90 days: Vendor receives CTA art work for the designated month.
80 days: Vendor submits proofs for CTA approval.
30 days: Vendor delivers 16,000 printed cards. CTA begins encoding 15,000 cards and invalidating 1,000 cards.
20 days: CTA's encoding group transfers 15,000 cards to CTA's distribution group and also transfers 1,000 cards for agent and driver bulletin boards.
10 days: Cards go on sale to the public.
0 days: Cards go in use.

3.2 Monthly Graphics

Each monthly group of cards shall have its unique graphics in up to four colors as designed by the CTA. The art work may define printing on one or both sides of the card with a maximum total of four impressions. The CTA shall furnish "camera ready" art work to the vendor with the lead time designated as above.

3.3 Printed Month

Each monthly group of cards shall be imprinted with the appropriate month as designated by the CTA art work.

3.4 Printed Serial Number

Each card in the monthly group shall be imprinted with a unique serial number in the range of 1 to 16,000.

The location shall be determined jointly by the vendor and the CTA group responsible for the graphics. Once determined, the location shall not change from month to month.

3.5 Printed Arrow

The printed graphics shall include a printed arrow to indicate the correct orientation and direction of travel of the card during a "read".

3.6 Signature Area

The graphics shall include space on the face of the card with appropriate printed instructions and surface treatment for the users validation signature.

4.0 MAGNETIC PROPERTIES

4.1 Location

The magnetic stripe shall be located on the card so that it allows encoding per American Banking Standard for data track 2 and meets the dimensional requirements of Figure A.

4.2 Coercivity

The magnetic stripe material shall have a coercivity of 3600 plus or minus 20% oersteds.

4.3 Uniformity

The uniformity of the magnetic material shall be appropriate for a process of recording digital data at a density of 75 bits per inch using a two-frequency, coherent phase method and obtaining a "uniform" recording as hereafter defined. A magnetic coating shall be considered acceptable in magnetic uniformity if sample cards pass the following test. The card shall be recorded at a constant speed with a series of "one" bits and then read at a constant speed, while recording the read head voltage. If the read head recording has less than 10% variation from the minimum pulse height, the coating is considered acceptably uniform.

4.4 Signal Level

The magnetic material shall be capable of producing peak readback signal voltages of not less than 100% or more than 200% of the read head voltage calibration when written with any current between 350% and 500% of a defined write head current calibration; see Figure B.

The 100% read head voltage calibration is defined as the maximum peak read back signal obtained from a saturation plot of a "secondary signal amplitude reference tape" (card mounted). The reference tape is the "Standard Reference Material (SRM) 3200 as given in American National Standard Unrecorded Magnetic Tape for Information Interchange (9 track 200 and 800 CPI, NRZI, and 1600 CPI, PE), x3.4-1983 corrected to the primary standard, written at 200 flux reversals per inch (FRPI), nonreturn to zero,

and transported at a velocity equal to that of the card encoder/reader.

The 100% write head current calibration is defined as that square wave current required to achieve 80% of maximum voltage from the National Bureau of Standards tape, corrected to the primary standard.

Saturation plots for both the SRM 3200 tape and the card specimen shall be conducted using the same set of write heads and read heads, and associated electronics and the same transport velocity.

Write heads and read heads shall be aligned for maximum signal transfer on both the tape transport and the card encoder/reader.

Transport velocity difference shall be kept to an absolute minimum. Saturation plots shall be performed at velocities such that head frequency response remains constant.

4.5 Information Density

The readback signal at 500 FRPI shall be no less than 70% of that obtained at 200 FRPI, provided that:

- The write current and all other parameters are identical to those of the 200 FRPI case, and the read head used in both cases has a gap or 0.0005 inch or less, and the resolution of the read shall be within the range of 95% to 100% when resolution is defined as, AMPLITUDE at 500FRPI X 100 / AMPLITUDE at 200 FRPI.

4.6 Reproduction Tests

The vendor shall submit 12 sample cards which conform to the preceding requirements of Section 4 of this Specification within 2 weeks of receipt of order. The CTA shall test these cards for magnetic properties and, if found to be in conformance with this Specification, will notify the vendor of permission to proceed with production. Failure to submit satisfactory preproduction "magnetic" samples in compliance with this Specification shall be sufficient cause to cancel the order. Additional cards may be requested by the CTA if tests on the initial group of cards are unsatisfactory for any reason.

5. PACKING FOR SHIPMENT

The cards shall be packed in consecutive order of the serial numbers and all the numbers shall be supplied when the cards are shipped from the Contractor to the CTA.

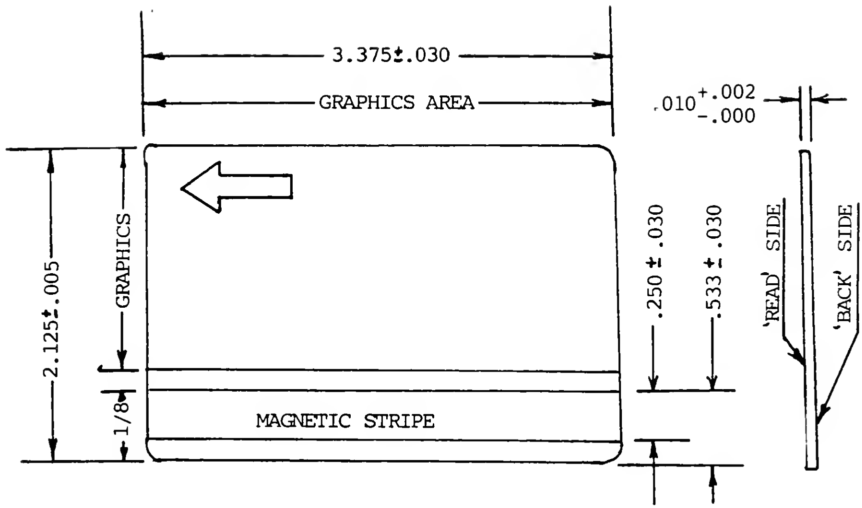
3.375±.030
GRAPHICS AREA
.010 +.002 -.000
2.125±.005
GRAPHICS
1/8
MAGNETIC STRIPE
.250 ± .030
.533 ± .030
'READ' SIDE
'BACK' SIDE

FIGURE A

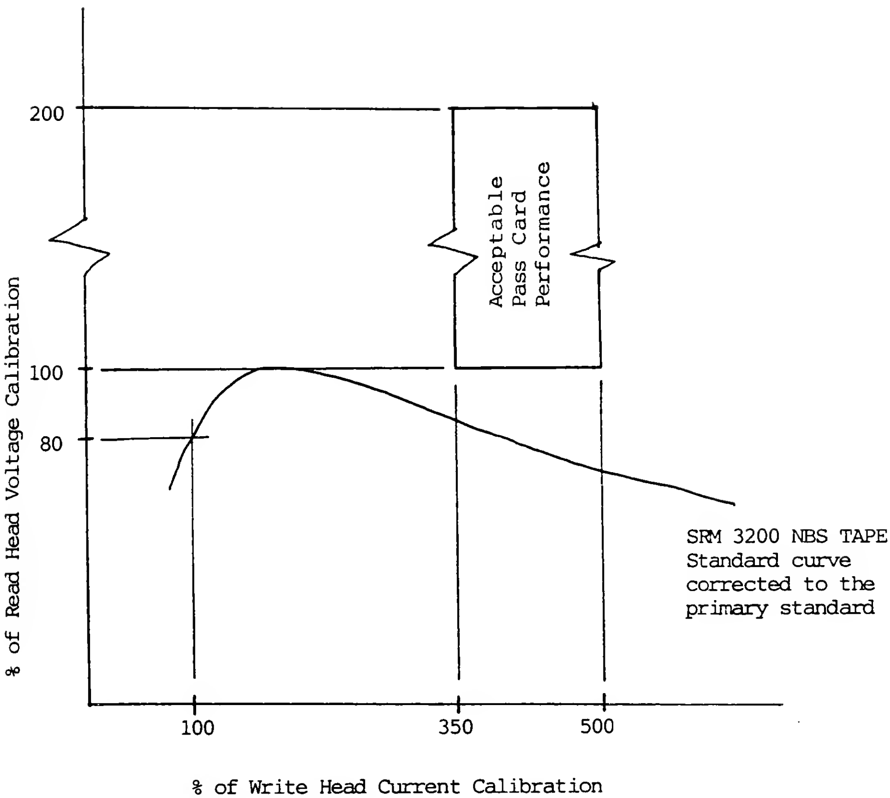

FIG. B

SATURATION CHARACTERISTICS